can find no parallel in other departments of

human activity. It was in the year named

hand, and as he perceived the answer to be

coming out right, all the scope and meaning

of his discovery came with a blinding flash

upon him. He could no longer see the paper

he threw down the pen; the secret of the uni-

But, of course, the proof had to be worked

out. The meaning of the discovery might

flash upon Newton, but the demonstration of it

in detail required years to elaborate. For two

ject. During that time he lived but to calcu-

late and think, and the most ludicrous stories

are told concerning his entire absorption and

inattention to ordinary affairs of life. It was

by this continuous application that the Prin-

cipia was accomplished, and it may be that

nothing of the first magnitude can be achieved

without a like absorbed unconsciousness and

freedom from interruption. But, though de-

sitable and essential for the work, it was a se-

vere tax upon the powers of the man. There

is, in fact, no doubt that Newton's brain suf-

fered temporary aberration after this effort

The attack was slight, and it has been denied.

able upon any other hypothesis. The de-

temporary, and it is only instructive as show

ing at what cost such a work as the Principle

What is the law of gravitation? It is, of

course, that every particle of matter attracts

every other particle of matter with a force

proportional to the mass of it and to the in-

verse square of the distance between them.

The following are some of Newton's deduc

tions from this law: In the first place, by

knowing the length of the year and the dis-

tance of any planet from the sun, the sun's

mass can be calculated in terms of that of the

earth. So too, the mass of any planes nossess

ing a satellite can be computed. Again, since

the moon is attracted not only by the earth.

but by the sun also, its orbit is perturbed.

and Newton calculated out the chief of

these perturbations. As, moreover, each

planet is attracted not only by the sun.

but by the other planets, their orbits

are slightly affected by each other. It was

Newton who began the theory of planetary

perturbations. He also recognized comets

as members of the solar system obedient

to the same law of gravity and moving in

very elongated ellipses; hence he showed

their return could be predicted, as in the case

of Halley's comet. Applying the idea of cen-

trifugal force to the earth, considered as a re-

tating body. Newton perceived that it could

not be a true sphere, and calculated its oblate-

ness, obtaining an excess of twenty-eight

miles for the equatorial over the polar diame-

observed shape of Jupiter or any planet

mated. The shape of the earth thus

calculated must in combination with cen-

trifugal force cause the weight of bodies

to vary with latitude. Newton computed

the amount of this variation and showed

that 194 pounds at the pole would balance 195

pounds at the equator. He then proceeded to

demonstrate that the earth's equatorial pro-

the sun and moon, must disturb its axis of

rotation in a calculable manner; thus is pro

duced the so-called precession of the equi-

noxes. Again, the waters of the ocean are at

tracted toward the sun and moon on one side

and whirled a little further away than the

solid earth on the other side; hence Newton

explained all the main phenomena of the

tides. The sun's mass being known, he calcu

lated the height of the solar tide, while from

the observed heights of spring and neat fide

he determined the lunar tide, and thence

Such are some of the gems extracted from

their setting in the "Principia" and presented

by Prof. Lodge with remarkable distinctness

and simplicity. It is hard, indeed, for any one

to realize the tremendous flight in knowledge

which was needed to span the distance between

Galileo, and the wild speculations of Descartes, on the one hand, and Newton's magnificent

system of comprehensive and well-ordered

knowledge. To many of Newton's contempo

raries it seemed as if there were nothing more

to be discovered -as if the universe were now

explored and only a few fragments of truths

remained for the gleaner. Newton himself

was far from imagining that he had exhausted

mite an old man, venerated and almost wor-

well-known words: "I know not what the

world will think of my labors, but to myself

playing on the senshore, now finding some pebble rather more polished and now some

shell rather more agreeably variegated than

VI.

travel instantaneously, but gradually, and that the motion of light was compounded with the

notion of the earth. Bradley demonstrated

f light, and pointed out the method of deter-

roved must be ten thousand times as great as

the velocity of the earth in its orbit; that is to

say, it must be 190,000 miles a second, not very

tured in order to explain the anomalies of

We come now to the nebular hypothesis.

which, indeed, had been suggested by Kant, but which has been principally commended to

different from the speed Rosmer had conject

Jupiter's first satellite.

the existence and the cause of the aberration

mining its velocity. The velocity of light he

Not long after Newton's death two great

tended itself unexplored before me."

nother, while the immense occan of truthez-

seems that I have been but as a child

the possibilities of discovery. It was when

shipped by his coevals, that he uttered the

the gropings of Kepler, the elementary truths of

made an estimate of the mass of the moon.

tuberance, being acted on by the attraction of

ter. Conversely, he proved that from th

the length of its day could be

must be produced.

rangement was, however, slight as well as

verse was to one man at least revealed.

The Messrs. Macmillan have published book form a remarkable series of lectures delivered by Prof. OLIVER Longs at the Univer sity College, Liverpool. The title Pioneers of we is somewhat too broad for the contents I the volume, for the author confines himself to desgribing in popular language the great achievements in astronomy and the men by whom they have been made. Beginning with operateus and Tycho Brahe, Mr. Lodge proceeds to Kepler and Galileo, next to Descartes and Newton, and so on to Rosmer and Bradley. Lagrange and Laplace. Herschel and Bessel. Other lectures deal with the discovery of the asteroids and that of Neptune, with comets and meteors, and finally with the tides and planetary evolution.

Nicolas Copernik, better known by the Latintred form of his name, Copernious, is believed to have been a German, although he was born at Thorn in Polish Prussia and graduated at Cracow University. He was instructed in tronomy at Cracow, and learned mathematics at Bologna. Thence he went to Rome. where he was made professorof mathematics. and soon afterward he went into orders. On his return home he took charge of the principat church in his native place, and afterward moved to Frauenburg, near the mouth of the Vistula, where he spent the rest of his life. It is noteworthy that to Polish Prussia we owe the earliest of modern astronomers as well as the greatest of modern philosophers, Kant. Copernious was a quiet, scholarly monk whose life was passed in study and meditation. His first work in astronomy was the compliation of tables of the planetary motions.

which were far more correct than any which had hitherto appeared, and which remained vervicesble long afterward. The Ptolemaid system of the heavens which had remained the orthodox conception throughout the Christian era, he endeavored to improve and simplify by the hypothesis that the sun was: the centre of the planetary system instead of the earth. The first consequences of this change he wrought out for many years, producing in the end the famous work "On the Revolutions the end the famous work ' of the Celestial Orbs," which embodies all his paintfaking calculations, and applies his new theory to each of the bodies in the solar evetem. Not until the very end of his life was the book put into type, but a printed copy was brought to his bedside so that he might feel it before he died.

The revolutionary consequences of his hy notheris were not appreciated at the time partly because his teaching was buried in ponderous and learned treatise, partly be cause the teacher was an ecclesiastic, mainly because he was a patient and judicious man content to state his views in quiet conversation and let them gently spread for thirty before he published them. When he did publish them he dedicated his book to the Pope, and induced a Cardinal to bear the expense of printing. Thus the Roman Church was made to stand sponsor to a system of as tronomical doctrine against which in the next century it was destined to burl its anathemas and to inflict on its conspicuous adhertorture. imprisonment, and achievement of Copernious may be summed up in a sentence. He demonstrated the truth of a theory said to have been taught by the Pythagoreans and Aristarchus, but which had against it the great weight of Aristotle's authority and which was new to the modern world. He put the sun in its true place as the centre of the solar system; he greatly simplified the theory of clanetary motions by this step; he exhibited the precession of the equinoxes (discovered by Hipparchus) as due to a conical motion of the earth's axis; and by means of a simpler theory and more exact planetary tables, he reduced to some sort of order the confused chaos of the Ptolemaie system. Copernicus himself felt the hypothesis of the motion of the earth to be a difficulty. Mr. Lodge points out that its acceptance is by no means such an easy and childish matter as we are apt now to regard it, and the hostility to it is not at all surprising. The majority of the men of the present have grown accustomed to hear of the earth spoken of; their acceptance of it means nothing; the attitude of the paradoxer who denies it evinces more intelligence. The author ac knowledges for himself that it was a long time before he could realize the revolution of the earth. Think, he says, of the solid earth. with trees and houses cities and countries mountains and seas-think of the vast tracte of land in Asia, Africa, and America—and ther pleture the whole mass spinning like a top and rushing along its annual course around the sun at the rate of nineteen miles a second. Then, again, to imagine a possible antipode must have been a tremendous obstruction in the way of conceiving the earth as a sphere Mr. Lodge has found that intelligent children invariably feel the greatest difficulty in realizing the existence of inhabitants on the opposite side of the earth. Of course, stupid children, like stupid persons in general, will believe anything they are told; but the kind of difficulties felt by intelligent and thoughtful children are most instructive, since it is certain that the early philosophers must have encountered and overcome these very same difficulties by their unaided genius. Nor are the difficulties involved in the concer-

tion of the earth as a sphere revolving round the sun only physical; they are still more felt from the speculative and theological points of view. Even now the reconciliation of theology with astronomy can hardly be considered complate. Theologians, indeed, do not deny the fact of the extreme subordination of the earth in the scheme of the universe, but many of them ignore it. So soon as the Roman Church awoke to a perception of the tremendous and revolu tionary import of the doctrines of Copernicus. it was bound either to resist them or else to b false to its traditions. For the whole tenor of men's thought would be changed if they a cepted it. If the earth were not the central and all important body in the universe, if th sun and planets and stars were not attendant and subsidiary lights, but were other worlds larger, and perhaps superior to ours, where was man's place in the cosmos, and when were the doctrines which the Church had maintained to be irrefutable? It was not t be expected that such a revolution would be accepted in a day, or in a century; and the plan naturally adopted by the Church was to treat it as a heresy and try to crush it out. Inasmuch, moreover, as scientific progress

was vastly slower in the sixteenth century than it is now, not only all priests, but even many astronomers, one hundred years afte Copernicus, still imagined the earth to be at rest. Among the men of science who still adhered to the Ptolemaic system, although he was born three years after the death of Coper nicus, was Tycho Brahe. By birth a Danish noble, he was sent to the University of Copenhagen to study law, but was attracted to astronomy by the occurrence of an oclipse on the predicted day. He began to construct astro nomical instruments, and produced a quad-rant and a sextant. With funds provided by the King of Denmark, he built Uraniburg, the first modern observatory, provided it with means of accurate observation not equaled at the time or for long afterward, and becam the founder of instrumental astronomy. His theories were poor, but his observations were admirable. He introduced a precis suration before undreamed of, and though hi measurements according to modern ideas are ludierously rough the such thing as a tel scope or a microscope having been invented), yet, in view of the era at which they were made, they are marvels of accuracy, and not single mistake due to carelessness has ever buon detected in them. For certain purposer onnected with the proper motion of the star they are still appealed to, and they served as trustworthy data for several succeeding generations of theorists to work upon. It was long indeed, after Tycho's death before observations approaching in precision to his were made in the true sense of the word he was a pioneer.

H. If everything else that he did were forgotter Troho Brahe would still be rem

teacher of Kepler. The son of a poor officer in the army of the Duke of Würtemberg, he was at first a tavern pot boy, but was ultimately sent to a charity school and thence to the University of Tübingen. He studied mathematics and accepted an astronomical lectureship at Graz. In 1507, at the age of 26, he published his first fanciful hypothesis, by which he endeavored to discover some concection between the number of the planets, their times of revolution, and their distances from the sun. Two years later he was invited by Tycho Brahé to Prague, whither the Danish astronomer had retired from his native country. After incredible labor, through innumer able wrong guesses, and six years of almost incessant calculation, Kepler at length emerged with his two first "Laws"discoveries which swept away all epicycles, deferents, equants and other remnants of the Greek avatem, and ushered in the dawn of modern astronomy. These awa, it is well known, were, first, that the planets move in ellipses with the sun in one focus, and, second, that the radius vector (or line joining the sun and planet) sweeps out equal areas in equal times. Ultimately, Kepler discovered the connection between the times and distances of the planets, for which he had been groping through all of his mature life. This law, which he announced in 1618, is that the square of the time of revolution (or year) of each planet is proportionate to the cube of its mean distance from the sun. His three laws, taken together, place him in the very highest rank of scientific men. They introduced order and simplicity into what else would have been a chaos of the details of observation, and they served as a secure basis or the splendid fabric to be reared on them

by Newton. To realize what Kepler did for astronomy it is necessary for us to consider some science still in its infancy. Astronomy is now so thoroughly explored that it is difficult to put one's self into the attitude of the men of the sixteenth century. Let us take, then, some other science, still barely developed, like meteorology, for example. The science of the weather-the succession of winds and rain. sunshine and frost, clouds and fogs-is now very much in the condition of astronomy before Kepler. Observation is heaped on observation, tables are compiled, volumes are filled with data, the hours of sunshine are recorded, the fall of rain, the moisture in the air. of facts; but where is the Kepler to study and prood over them? Where is the man to spend his life in evolving the beginnings of law and order from the midst of all this chaos? of such labor, crowned by three brilliant disoverles, was that of Kepler. The experimental observer is indispensable, but how backward would science be were observations not interpreted by thinkers like Copernicus. Kepler, Newton, and Laplace.

111. A contemporary of Kepler was Galileo. The latter was born in the year 1564, in which Mishael Angelo died, and he died in 1642, the

year in which Newton was born. The perseution of Galileo did not begin until 1615, nor become intense until 1632; from the lastnamed date it lasted till his death. Born at Pisa, Galileo studied medicine in the university of that city. He was an experimental o server. It was by experiment that he refuted the assertion of Aristotle that bodies fall at rates depending on their weights. Galileo, on the contrary, contended that the weight did not matter in the least, but that everything would fall at the same rate, even a feather but for the resistance of the air, and would reach the ground at the same time. To convince his opponents, he ascended one morning the famous leaning tower of Pisa, taking with him a 100-pound shot and a one-pound shot. In the presence of the assembled university he balanced them on the edge of the tower and let them drop together. Together they fell and together they struck the ground. This victory over the Aristotelians made Galileo unpopular in Pisa, and he presently found his professor's chair untenable. Having received the offer of a professorabin at Padua from the Senate of Venice he accepted it, and began a successful career. It was at Venice that Gali leo invented the telescope. He had heard, to be sure, of a toy constructed by a Dutch or tician out of a couple of spectacle lenses through which, if one looked, the weather cock of a neighboring church spire was seen nearer and upside down. Galileo's instru ment was made on another plan from that o the Dutch optician. He took an old and small organ pipe, jammed a suitably chosen spectacle glass into either end, one convex, the other concave, and thus produced the half of a wretched opera glass capable of magnifying three times, It oy, because it did not invert. Even with this rude telescope it was possible to make ships visible from one of the highest towers in Venice two hours before they were seen en tering the harbor. Subsequently Galileo suc ceeded in making a telescope magnifying thirty times. Equipped with this he was ready to begin a survey of the heavens. The firs object he examined was the moon, where he found everything at first sight very like the earth-mountains and valleys, crators and plains. To the disgust of the Aristotelians, he not only made the moon like the earth, but he made the earth shine like the moon. explaining by earth-shine the visibility of "the old moon in the new moon's arms." One of the stock arguments against the Copernical theory of the earth being a planet was that the earth was dull and dark, and did not shine. Gailleo argued that it shone just as much as the moon does, and, in fact, rathe more, especially if it be covered with clouds, Seen from the moon, the earth would look exactly as the moon, does to us, only a little brighter and sixteen times as big. It is note worthy that Galileo made a very good estimate of the height of lunar mountains, of which many are five miles high and some as much as seven. Wherever in the firmanent (inline urned his telescope new stars appeared. The milky way, which had so puzzied the ancients was found to be composed of stars. His mos brilliant achievement was the discovery of the our moons of Jupiter. His opponents contended that there were more than four, but no proof of the assertion was furnished until last year, when news from the Lick Observators made the existence of a small fifth satellite of Jupiter not improbable. It should also be remembered that Galileo invented a thermometer and a microscope. If we pass from his achievements in invention and observation to the results of study and meditation we must regard as his weightlest performance his formulation of the laws of motion, the outcome of the application of mathematics to experiment. We have seen hew he shower hat all bodies fall at the same rate, except for the disturbing effect of the resistance of the air. What is this rate? The height through which a dropped body falls is not proportion to the time simply, but to what is called the square of the time, that is, the time multiplied by itself. Thus, in one second, a freely falling body near the earth is found to drop sixteen feet. In two seconds it drops sixty-four feet. that is, sixteen muitiplied by the square of two. In three seconds it drops 144 feet, or sixteen multiplied by the square of three, and so on. The fact that the height through which a

considered constant; under such circum stances the Galilean law of the square of the time does not hold. Whether Bruno was executed for heresy is still disputed, but there is no doubt that h was imprisoned for teaching the plurality of worlds, the Copernican theory of the motion of the earth, and other heterodox doctrines. His death occurred in 1000, and his treatment would naturally make a deep impression upon Galileo. Nevertheless, while still a professor at Padua, and not long after Bruno's death, he threw down the gauntlet in favor of the Copernican theory, regudiating the old Ptolemaio system which up to that

body falls is proportional to the square of the time, proves that the attraction of the earth or

the intensity of gravity may be regarded as

constant through ordinary amail ranges

Through great distances gravity cannot be

time had been taught in the university. He continued to teach the Constructan doctrine after his removal from Padus to Tuscany, and n 1615 Pope Paul V. requested him to come to Rome to explain his views. He made a most uccessful visit, maintaining his opinions against fifteen or twenty disputants, and confounding his apponents. He had an au-dience with the Pope, and the two parted good friends; he also made a special friend of Cardinal Barberino, who became the next Pope. Notwithstanding these pleas-ant features of his reception the Copernican system was condemned; both the book of Copernicus and Kepler's epitome of it were placed on the forbidden list (where they remained till 1835); and Galileo himself was for mally ordered never to teach or believe the motion of the earth around the sun. Galileo returned to Florence in disgust, but he would have remained unmolested had he not, after the accession of his personal friend, Cardinal Barberino to the Papal throne in 1623, brought out his greatest literary work. " Dialogues on the Ptolemaic and Copernican Systems." It was said by his enemies that his friend, the Pope. was represented in the character of Simplicio an Aristotelian philosopher, who was made to propound the stock absurdities which served in lieu of arguments to the majority of men. Whether Urban VIII. believed the charge or not, it is certain that his favor thenceforth withdrawn from Galileo. and in 1632 the latter was summoned to Rome. where he was examined by the Inquisition. For some time the Inquisition dealt with him as leniently as possible. Although frequently interrogated between February and June. 1033, he was not then subjected to torture. What happened during the three days between chambers of the Inquisition, is to this day a matter of controversy. Several eminent scholars have held the fact of actual torture to be indisputable, finding conclusive evidence in the hernia from which he afterward suffered, this being a well-known and frequent outcome of the rack. Other commentators, equally learned, deny that the torture stage was reached. What is certain is that, at some time during those three days and under pressure, either physical or moral, the old man -he was seven ty-consented to recant. On the day after his removal from the chambers of the Inquisition he was taken to the Convent of Minerva. where, in the presence of the Cardinals and prelates assembled for the purpose, he for mally abjured the belief that the earth is not the centre of the universe and the belief that t is movable. They who credit the story about his muttering to a friend as he ros from his knees "E pur si muore" (for all that, it moves) do not appreciate the situation Galileo had no friend in the place, and i would have been fatal to mutter any thing before such an assemblage. More over, he was by this time an utterly broken and disgraced old man, wishfu of all things to get away and hide himself and his miseries from the public gaze; probably with his senses deadened and stupefied by the mental sufferings he had undergone, and no longer able to think or care about anything except, perhaps, his daughter, who was then lying on her deathbed. Condemned to a solitary existence at Arcetrl, he yet found energy enough to compose the dialogues in which he true laws of motion are set forth for the first time, and which, as we have said, are now accounted his most solid achievement. One more astronomical discovery he was to make, that of the moon's libration, and then fell a final crushing blow; he became totally blind-Yet he lived five years longer, during which he was visited by John Milton, who has recorded the pathetic incident in one of his most memtined in his old age to suffer the same fate.

orable prose compositions, and who was des-We have said that Galileo died in the year 1642) in which Newton was born. What scientific name deserves to rank between thom? Many persons would say that of Bacon. but Bacon's claim is rejected by Mr. Lodge o the ground that he was a literary man and not a scientist, and that his so-called rules for making discoveries have never been consciously or often unconsciously followed by experimentalists. Bacon sneered at the work of Galileo and rejected the Copernican theory as absurd. It is accordingly Descartes whom the author of this volume would place between Galileo and Newton, although the most important work of Descartes was done in philosophy, mathematics, physics and anatomy chief scientific achievement was the application of algebra to geometry, and he is mainly connected with astronomy by his now abandoned "theory of vortices," invented to account for the motions of planets. Descares had no notion of suffe his opinions. When he heard of the persecution and recantation of Galileo, he deferred to ten years the publication of his Principia Mathematica, and, when he ultimately printed it. formally denied that the earth moved. The truth, of course, was that Descartes cared nothing at all about the Church or its dogmas. He was a skeptic, yet not in the least an athe ist, for a great part of his philosophy was oc-

cupied with what he coasidered a rigorou proof of the existence of the Deity. To those who exalt experiment at the ex ense of deduction, Mr. Lodge points out that Descartes was a precursor of Newton in thi respect, that his general method of research was as nearly as possible a purely deductive one. That is to say, he starts after the manner of Euclid with a few simple principles, and then by a chain of reasoning endeavors to deduce from them their consequences, and so to build up, bit by bit, an edifice of connected knowledge. It is true that this method cannot be safely followed without continual ap peals to experiment for verification. It was through not perceiving the necessity for such appeals that Descartes erred. His importance to science lies not so much in what he actually discovered as in his anticipation of the right conditions for the solution of problems physical science. He, in fact, made the discovery that nature could, after interrogated mathematically, a fact that was in great danger of remaining unknown. A reaction against deductive reasoning had set in, led by Galileo, persisted in by the whole modern school of experimental philosophy. and lasting down to he present day. It is not true, however, that the only right way of investigating nature is by experiment and observation. This is, indeed, an absolutely necessary way, but it is not the only way. A foundation of experimental fact there must be; but upon this a be based, all rigidly connected together by pure reasoning, and all necessarily as true a the premises, provided no mistake has been made. To guard against the possibility of mistake or oversight, all conclusions must sooner or late; be brought to the test of experiment. If the test cannot be borne the theory itself must be reexamined and the flay discovered, or else the theory must be atanloned. Of this deductive method, which in the hands of Newton was to lead to such stupendous results, and which combined with experiment, has made science what it is, we owe the beginning and early stages to Descartes.

Three chapters of this volume are devoted to Newton, and in one of them is given a singularly clear account of the principal discoveries set forth in the Principle. As this so count is given in popular language, without any recourse to technical terms, we shall pres-ently mark some features of it. But, first, we will recall hastily the chief outward features o Newton's life. Born, as we have said. in 1642, be died in 1727, at the age of 85. His father was a smal: freehold farmer of Lincolnshire At the age of 15, the boy Isaac was remov ed from school to be made a farmer of. but as he did not promise to turn out a good one, his mother's brother, who was a parson, arranged to send him back to school, and thence to Cambridge, where he entered Trinity College as a sub-sizar in 1661. The Cambridge men who used to sneer at sizars must have forgotten that Newton was one of them. At the university Newton stud

led the geometry of Descartes; found out for himself a method of infinite more solid though Jess brilliant man, and it is impossible to apportion the respective shares of credit between these two men, the greatest series and began the invention of fluxions. In 1606 he was driven from Cambridge by the scientists that France has produced. Between them they explained the libration or oscilla plague, and, while staying at his native village in Lincolnshire, the famous apple fell, which, ion of the moon, which had been discovered as he afterward recorded, suggested the train by Galileo just before his blindness—the long inequality of Jupiter and Saturn, the former lagging behind its true place, while the motion of reflections resulting in the discovery of the aw of gravitation. At the age of 28 he became a professor of mathematics at Cambridge, and of Saturn is being accelerated, the parturbaectured on optics with great success. Three tions of Jupiter's satellites and of comets—and years later he communicated to the Royal So-clety the outcome of his optical researches. the acceleration of the moon's mean motion. The same two scientists improved the tunar including his reflecting telescope, his discovtheory and the theory of the tides, acery of the compound nature of white light, counted for the periodic changes in the and his observations in diffraction. He also, form and obliquity of the earth's orbits, at this time, invented the modern sextant. In and demonstrated the stability of the solar 1672 he began the Principla, working in si system considered as an assemblage of rigid lence. The first part of this work was pub-lished in 1687 and the complete edition in 1713. bodies subject to gravity. It is obvious that the question whether the solar system is stable was one of stupendous moment. If any one planet of the solar system were to fall into In the year 1672, when Newton was but 30 years old, he had already accomplished enough for the life work of one man. He had discovthe sun, especially if it were a big one, like ered the nature of white light and the true Jupiter or Saturn, the heat produced would be doctrine of color, and he had invented the difso terrific that life on this earth would be deferential calculus. He had achieved other stroved, even at its present distance. We owe memorable things, such, for instance, as the to Lagrange and Laplace the proof that the binomial theorem, the reflecting telescope changes of the solar system are not cumuand the sextant. The masterpiece remains ative, but periodic; that is, they repeat themunmentioned, the achievement whereby New selves at regular intervals, and never exceed a ton towers head and shoulders over not only a certain moderate amount. The period, to be of his contemporaries, but over every scientific sure, is something enormous. The members of man who has ever lived. in a way for which we our solar system will not have gone through all

1672) that Newton heard of the careful dethe planetary oscillation. "a great pendulum termination of the length of a degree—in othe of eternity which beats out ages as our pendu words, of the size of the earth-which had lums beat seconds." been made by Picard, near Parls. The The nebular hypothesis was thrown out by length of the degree turned out to be Laplace, not as the outcome of profound calnot sixty miles, but nearly seventy miles. culation. like the demonstration of the sta-Armed with this new fact, Newton turned bility of the solar system, nor as following cerback to his old speculation concerning gravity tainly from the theory of gravitation, and He had worked out the mechanics of the therefore it is not to be accepted as more than solar system on a certain hypothesis, but it a brilliant speculation, to be confirmed or rehad remained a hypothesis somewhat out of jected, as our knowledge extends. Since the harmony with apparent fact. He took out his time of Laplace the nebular hypothesis has old papers and began again the calculation had ups and downs of credence, but at the If gravity were the force keeping the moon in present time it holds the field with apparently its orbit, it would fall toward the earth sixteen greater probability of ultimate triumph than feet every minute. How far did it fall? The has ever before seemed to belong to it. With the help of Prof. Lodge, let us try to newly known size of the earth would modify the figures; with intense excitement Newton ran through them, his mind leaping before his

their changes of position until a period of two

million years has clapsed. This is the term of

state the nebular hypothesis in a compact and intelligible form. We should, in the first place, recapitulate the data on which it is founded. They are these: Every motion in the solar system known in Laplace's time took place in one direction, and in one direction only. Thus the planets revolved around the sun, all going the same way round; moons revolved round the planets, still maintaining the same direction of rotation, and all the bodies that were then known to rotate their own axes did so with the same kind of spin. Moreover, all these motions take placin or near a single plane. The ancients knew that sun, moon, and planets all keep near to the plane of the seliptic within a belt known as the zodiae; none strays away into other parts of the sky. Satellites, also, and rings are arranged in or near the same plane, and the plane of diurnal spin or equator of the different bodies is but slightly tilted.

Manifestly, all this could not be the result of chance. What could have caused it? Is there any connection or common ancestry to account for this strange family likeness? There is no connection now, but may there not have been one once? Must there not have been one, we should rather say? It seems as though they had once been parts of one great mass rotating as a whole, for, if such a rotating mass broke up, its parts would retain its di-rection of rotation. But such a mass filling all space as far as or beyond Saturn. although containing the materials of the whole solar system in itself, must have been of very rarefled consistency. Occupying so much bulk, is could not have been solid, nor yet liquid, but it might have been gaseous. Are there any such gigantic rotating masses of gas in the heavens now? Certainly there are: there are the nebulæ. Some of the nebulæ are now known to be gaseous, and some of them, a east, are in a state of rotation. Laplace could not have known this for certain, but, he suspected it. The first distinctly spiral nebula was discovered by the telescope of Lord losse; and quite recently a photograph of the great Andromeda nebula, made by Mr. Isaac Roberts, demonstrates that this prodigious mass is in a state of extensive and

majestie whirl. The problem presented by the data is the ollowing: A vast mass of rotating gas is left to itself to cool for ages and to condense as it ools; how will it behave? Laplace picture o himself this mass shrinking, and thereby whirling more and more rapidly. A spinning body shrinking in size and retaining its original amount of rotation, as it will unless a brake is applied, must spin more and more rauishrinks. It has what mathematicians call a constant momentum, and what it loses in leverage as it shrinks it gains in speed. The mass s held together by gravitation, every particle attracting every other particle, but, since all the particles are describing curved paths, the will tend to fly off tangentially, and only a small excess of the gravitation force over the centrifugal is left to pull the particles in and slowly to concentrate the nebula The mutual gravitation of the parts is opposed by the centrifugal force o the whirl. At length a point is reached where the two forces balance. A portion out side a certain line will be in equilibrium. It will be left behind, and the rest must contract without it. A ring is formed, and away goes the inner nucleus, contracting further and further toward the centre. After a time auother ring will be left behind in the same way, nd so on. What happens to these rings? They rotate with the motion they porsess when thrown or shrunk off, but will they remain rings? If perfectly regular they may: if there be any irregularity they are liable to break up. They will break into one or two r more large masses, which are ultimately very likely to collide and become one. The revolving body so formed is still a rotating. gaseous mass, and it will go on shrinking and cooling and throwing off rings like the nucleus by which it has been abandoned. As any nucleus gets smaller, its rate of rotation nereases, and so the rings last thrown off will be spinning faster than those thrown off earlier. The final nucleus or residual central

body will be rotating fastest of all. The nucleus of the whole original mass which once contained all the materials of our solar system we now see shrunk up into what we call the sun, which is spinning on its axis once every twenty-five days. The rings successively thrown off by it are now the planets, some large, some small-the last thrown off rotating around the sun comparatively quickly, those outside much more slowly. The rings thrown off by the planetary gaseous masses as they contracted have now become satellites, except one ring which has remained without breaking up, and is to be seen rotating around Saturn still. One other similar ring, an abortive attempt at a planet, is also left around the sun, vis., the the so-called asteroids. Such, stated in a few sentences, is the hypothesis tirst propounded by the philosopher, Kant, but claborated in much fuller detail by Laplace, the greatest of French mathematicians and astronomers.

discoveries were made by another English man. Prof. Bradley of Oxford, namely the aber-We have but little space in which to touch on ration of light and the nutation of the earth's xis. Some fifty years earlier, a Danish astronomer, Rosmer, had surmised that light did not

the last six chapters of Mr. Lodge's book. although these cover the field of recent astronomical discoveries, some of which are of extraordinary interest. We can only say of Frederick William Herschel that, while still an amateur, he first drew attention to Uranus. which he himself suspected to be a comet, but which was discerned to be a planet by professional astronomers; that he subsequently discovered two moons of Saturn and two of Uranus, besides 2,500 nebulm and 806 double stars; that he reviewed, described, and gauged all the visible heavens, and finally discovered that the stars were not fixed, but in notion, and that the sun, as one of them. was journeying toward a point in the constellation Hesoules. Whether we look at the quantity or quality of his work, we must pronounce Siz astronomers by Laplace. The latter worked William Herschel the greatest of observing very much in conjunction with Lagrange, a distinguished from theoretical astronomera.

What theorists can do was once more signally demonstrated by the discovery of Neptune through sheer calculations based on the per turbations of Uranus. It is now acknowledged that these calculations were carried on simul taneously and independently by Leverrier in Paris and Adams in Cambridge. The planet Neptune was first knowingly seen by Galle of Berlin on Sept. 23, 1840. Proeminently with the name of Bessel is as sociated the calculation of the distances of the

stars and the discovery of stellar planets. It was Bessel who, by means of the heliometer. solved the problem of stellar parallax, and thus enabled us to determine the distance and real rate of travel of many of the stars. The quickest moving stars as yet known are a double star of the sixth magnitude called 61 Cygni, and one of the seventh magnitude called Groombridge 1830. The velocity of the latter is 200 miles a second. The nearest known stars are 61 Cygni and a Centauri. The distauce of these stars from us is about 400,000 times the distance of the sun. Sirius is more than a million times further from us than ou aun is and twenty times as big. Many of the brightest stars are at more than double this distance. The distance of Arcturus is too great to measure even now. The stars it is well known, are suns, most likely surrounded by planets. One planet belonging to Sirius has been discovered. It was predicted by Bessel: its position was calculated by Peters. and it was seen by Alvan Clark in 1802. Another planet predicted by Bessel as belonging to Procyon has not yet been discerned, although its existence is credited. It is impossible for the human mind to fully

grasp the meaning of the figures representing the distance of the stars. Prof. Lodge essays to help us to comprehend them by the following surgestion: "Suppose," he says, "we could arrange some sort of telegraphic vehicle able o carry us from New York to Liverpool in the tenth part of a second-that is, in the time required to drop two inches-such a vehicle would carry us to the moon in twelve seconds and to the sun in an hour and a quarter. Travelling thus continually, in twenty-four nours we should leave the last member of the solar system behind us and begin our plunge into the depths of space. How long would it be before we encountered another object? nonth, would one guess? Twenty years we should have to journey with that prodigious speed before we should reach the nearest star, and then another twenty years before ve.should reach enother, at such awful distances from one another are the stars scatered in space; and were they not brilliantly self-luminous like our sun, they would be

There are, no doubt, multitudes of stars that will always be invisible to us, and some that can now be descried will not be visible hereafter. We have seen that the quickest moving stars are those known as 61 Crgni and Groombridge 1830. Owing to their relative quickness of motion, they have been described as flying stars. The actual speed of Groombridge 1830 is about 200 miles a second a speed greater than the whole visible firms. ment of 50,000,000 stars can control. Unless, therefore, the universe is immensely larger than anything we can see with the most powerful telescopes, or unless there are crowds of invisible non-luminous stars mixed up with the others, immensely multiplying the attractive power of the orbs visible, the star known as Groombridge 1830 can only be a temporary visitor to this frame of things. It is travelling from an infinite distance to an infinite distance; it is passing through our visible universe for the first and only time; it will never return. Yet so gigantic is the extent of visible space, that with its amazing speed of 200 miles every second this star will need two or three million years to get out of sight of our present telescopes, and several thousand years before it gets perceptibly fainter than it is now. VIII.

We would not wholly overlook a chapter in

which Prof. Lodge considers the nature of meteors or so-called shooting stars: We or dinarily see thom as more streaks of light: sometimes they leave a luminous tail behind them: occasionally they appear as actual fireballs, accompanied by explosions; some times, but very seldom, they are seen to drop. and may subsequently be dug up as lumps of iron or rock, showing signs of rough treatment by excoriation and hent. These last are the meteorites or aerolites of our museums. They are popularly spoken of as thunderholts though in reality they have nothing to do with atmospheric electricity. They appear to be travelling rocky or metallic fragments which, travelling rocky or metallic fragments which, in their journey through space, are caught in the earth's atmosphere and instantaneously ignited through the effect of friction. Far away in the depths of space one of these wandering bodies felt the attracting power of the sun and began moving toward it. As it approached, its speed graw gradually greater and greater, until, by the time it has approached to within the distance of the earth from the sun, it whizzes past with the velocity of twenty-six miles a second. It will be romembered that the earth is moving on its own account nineteen miles a second. If the two bodies happen to be moving no postis directions, the combined speed would be terrifle; and the faintest trace of almosphere miles above the earth's surface would exert a furious grinding action on the faintest trace of almosphere miles above the earth's surface would exert a furious grinding action on the faintest trace of almosphere miles above the earth of the surface would exert a furious grinding action on the faintest form of the faintest would be dissipated, shartered to fragments in an instant. On the other hand, if the earth and the closely of seven miles a second, and there then might be a change for a residue of the nucleus of the meteor to escape entire destruction, though it would be scraped, heated, and superficially molted by the friction of the earth's atmosphere nevertheless, so much of its speed would be rusteed out of it, that, on striking the earth, at might bury itself only a few feet or yards in the soil, so that it could be dug out. The number of meteoric stones, however, which thus heaten and superficially molted by the friction of the earth's atmosphere; nevertheless, so much of its speed would be rusteed out of it, that, on striking the earth, at might bury itself only a few feet or yards in the soil, so that it could be dug out. The number of meteoric stones, however, which thus he was a superficially mount of the soil of the soil of the soil of the moon must be something terrible. It follows then that every shorting start we see and all the myriads we cannot see because they occur in the daytime represent the death and burial of one of these lifting start we see and all the myriads we cannot see because they occur in the daytime represent the death and burial of one of these lifting stones. It has been careering on its own account through space for untold ages till it meets a planet. It enance, sa ruise is a sufficient series of which the mine is a sufficient series of which the mine is a sufficient series of the strikes of the partition, and that consequently suche

MRS. STANTON CALLS ON THE WOMEN. She Suggests Things that They Can Do to

To THE EDITOR OF THE SUN-Ser. Complaints as to the present condition of this city are numerous, but suggestions as to a remedy are few. Having poured out the vials of our wrath on the city authorities, let us consider our individual responsibilities in the uniform dirt and disorder of our streets, cars, and all public places. Neither the wisdom of Solomon nor the strength of Samson, with two millions of dollars annually to back them, could keep this city clean while a million of people do their uttermost to make it otherwise. Respectable men and women tear up letters in infinitesimal pieces and scatter them on the sidewalks: lawless boys pull-down sheets of advertisements and toss them up and down he streets; mikmen leave huge carts filled with tin cans standing on the Boulevard all

But to take up the nulsances in the order of

their obtrusiveness, let us begin with the papers which are most easily disposed of, though most glaring in appearance. They are an element of danger, too; blowing about, they frighten horses, and carry diseases from one heighborhood to another. We funigate letters from vessels that have had contagious diseases on board, and then let papers from hose eases on board, and then let papers from hose eases on board, and then let papers from hose eases on board, and then let papers from hose eases on board, and then let papers from hose eases on board, and then let papers from hose houses, and the slums of our city sport with the winds from the four points of the compass. While commissioner Brennan and his stallwart forces labor with the government of the city to see what they can do to releve the plethoric ash barrels, which have presented a most pathetic appearance in our streets for the last month. Let us begin by disposing of the papers. Each mistress of a house should see that all refuse papers in her domain are burned on her premises, either in the range, the furnace, on the pavoment in her back yard, or in the gutter in front. They should never be thrown into the ash barrel, to be blown through the streets as soon as the ashes are emptied. Women should teach the men of their families to do the same in their places of business anchould teach the men of their families to do the same in their places of business anchould teach the men of their families to do the same in their places of business anchould teach the hashes are emptied. Women should teach the hashes are deptically of the same and the places of their families to do the same in their places of business anchould teach the hashes are motived in their places. If we have any city ordinances forbidding people to throw refuse into the streets, we must ask Mayor (filtroy to have them printed in large letters and posted in all public places; in our schools to commence an educational work with our children, and is our kitchens to the hard part of the papers, bus their obtrusiveness, let us begin with the papers, which are most easily disposed of though nost glaring in appearance. They are an ele-

papers, cigar stumps, toothpicks, red tape and all, into the streets.

You never see papers scattered about in the streets of London or Paris, nor anything on the floors of even a third-chase ser in England, liut in all our American cities and villages papers are flying in all directions, and our cars, especially in the West, are more like pig pens, at the end of a day's journey, than travelling conveyances for the sovereign people of a great republic.

As the Exposition is to open in Chicago in a few mouths, we shall have visitors here from all parts of the world, and their first impression of us as a people will be made by the appearance of the streets of our metropolis, But the most critical visitor landing on our shores in the spring will be the choice a, a stern judge who will pry into all the nooks and corners, the lanes and courts, and punish us for our sins in dark places. Unless we make a thorough cleaning of all our cities we shall risk the success of the Exposition altogether.

We can no longer pose as an Infinit, and make our youth an excuse, for all our cities and people.

ELIZABETH CAPY STANTON.

BLOOMING IN THE GYMNARIUMS. Schoolboys Hard at Work for Their Favor-Ite Outdoor Sports,

The athletic schoolboys are taking all the advantages of gymnastic work nowadays. At Berkeley the candidates for the athletic team are kept in active daily training. Dudley and Cary, the two leading candidates, continue to improve, and they will be Berkeley's only representatives in the 100-yard dash for seniors. boys under 15 years old will be allowed to compete. F. Bien. C. Held. and Wilson will represent Berkeley. The school also has quite promising broad jumper in Bowers.

The pole vault is one of the new interscholastic events, and as yet there are only a few candidates. At Berkeley only one lad has thus far jumped into view, and he is Fred de Peyster. Dick Elliott is doing well in the 440-yard run, while in the half-mile run C. Irwin-Martin, De Peyster, and Pier are running well. Irwin-Martin will also enter for the one-mile run, along with E. Fahnestock, H. Crane, and Cunningham. Training for the one-mile walk are Teddy Bogert, Elliman, and F. Brower. Bogert is expected to capture the event for Berkeley. Some of the candidates for the other events are: Bayne and J. E. West, in the one-mile bicycle race; G. V. C. Richards and C. Osborn, in the hurdles; T. Ball, Elliotz, and C. Osborn, in the shot-put and hammerthrew, and Fitch, Bowers, Dudley, and M. Waterbury, in the high jumps. few candidates. At Berkeley only one lad has

and Fitch, Bowers, Dudley, and M. Waterbury, in the high imps.

The schoolboys will soon begin to talk baseball. The successor to the Interscholastic Athletic League will boom the sport this year. In the league are Columbia Grammar. Brooklyn Latin, and St. John's achools. New York Military and Montelair Military academies, and Stevens School of Hoboken. The Adelphians of Brooklyn may try to join some league. Arthur Otterson, the crack first baseman, has left the academy, and so has Eddle Plarre, who played third base and who captained the team hast spring. It is likely that Percy Edgar will be behind the bat and Burk Hodgson the pitcher. There is some talk of a Graduate Advisory Committee for the Adelphi. If this is formed it is probable that the Adelphi leams will be assured of some good coaching by graduates.

At Fratt Institute the boys are more and to

If this is formed it is probable that the Adelphi teams will be assured of some good coaching by graduates.

At Fratt Institute the boys are more apt to turn their attention to track athletics instead of baseball. Now that they have a gymnasium, the lads r ay do better. They have more inducement, however, to engage in track athletics. The athletes are drawn from the different schools of the institute. They are not confined to those students taking the regular course. The students in the architectural and mechanical drawing departments are made welcome on the athletic field. From the School of Architectural Drawing comes Bartlet, one of the best athlete in the mechanical drawing department. In the regular course are Alien 10% High theirs at the institute. Stebbins is the best athlete in the mechanical drawing department. In the regular course are Alien 10% Hartich, 10% Carl, 10% Richardson, 10% Lacour, 10% and Baylis, 10%.

The Brooklyn High School boys incline toward field sports. They never have done anything in track athletics, but their baseball and footbail teams have accomplished a great deal within the past few years. Next spring they are almost sure of having a winning baseball nine. They dovice all their afformoons to good, hard practice, and are not too lazy to go to Prospect Park to play, it will not be much of a surprise among the knowing one if the High School into win the champiouslain of long Island this spring.

Found a ( 112 Dweller's Mummy,

CHARLES CITY, I.A., Feb. 16. "Prof. Clement L. Webster of this city has returned from his extended researches and explorations among the ancient cliff dwellers' ruins of Mexico. New Maxico, and other portions of the Southwest. The greatest discovery which theyrofessor made was that of a perfectly prepared cliff dweller's mummy. Never before has a discovery of this kind been made. This mummy, which is that of a child apparently about 7 years of age, was discovered in a cliff dwelling on the Rio Gila, in the Mogolion mountains.

mountains.

The body is in a remarkable state of preservation, and is asther small when compared with that of a child of the same age of to-day. It is of a yellowish brown color, and is rather light in weight. Its arms are upraised near the sides of its head, the hands clinched, and the sides of its head, the hands clinched, and the legs are omewhat drawn up. The hair, which is perfectly preserved, is of a beautiful hrown color (like that of the adults found braided, and associated with it), and of a silky texture. The bedy had been carefully wrapped in two varieties of coarse cloth, such as was everywhere in this region made by the cilf dwellers, then carefully bound onto a peculiar shaped board of cottonwood. A mass of evidence in connection with the finding of this mummy was obtained, which demonstrates beyond a doubt the genuineness of this relic.